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EFFECT OF VARIATIONS IN FAT AND TEMPERATURE ON THE SURFACE TENSION OF VARIOUS MILKS[1, 2]

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SUMMARY

Measurements of the surface tension of skimmilk, whole milk, and homogenized milk were made at 60, 81, and 102° F. with a du Noüy tensiometer, to obtain data for use in the calibration of lactometers. The results are presented graphically. A consistent difference was apparent between the surface tensions of the three milks, with an increasing divergence occurring with a rise in temperature. The difference between the surface tension of skimmilk and whole milk was about 50% greater at 102 than at 60° F. The surface tension of homogenized milk was intermediate to that of skimmilk and whole milk. The change in the surface tension with temperature for all milks was most marked between 60 and 80° F. The surface tension of whole milk was not affected significantly by fat in excess of about 4%.

The present work on the surface tension of milk was done in connection with research on the calibration of lactometers to be used at the temperature of 102° F. *(18, 19)*. It has been the practice to verify the calibration of lactometers by reading them in sulfuric acid solutions of known specific gravity. The calculations involved in correcting the readings in acid on a basis of 60/60° F. to readings in milk on a basis of 102/102° are complicated, and the values obtained are made uncertain by the lack of information about the surface tension of milk at the different temperatures. Inaccurate corrections for surface tension in the calibration of lactometers can result in errors as large as 0.5 degree Quevenne *(9)*. A search of the literature revealed that information on the surface tension of various milks over the temperature range of 60–102° F. was meager, and entirely inadequate for the purposes of the study. Also, it has been pointed out that the calibration of lactometers should be verified by observations made on skimmilk and homogenized milk, in which any difficulties due to the rising of the fat can be avoided *(19)*. Therefore, a study of these milks was included in this investigation.

EXPERIMENTAL PROCEDURE

The experimental work was carried out with a du Noüy tensiometer which had been accurately calibrated *(4, 13)*, and which was equipped with a ring which had a mean circumference of 6 cm. Pyrex vessels with an inside diameter of 67 mm. and a depth of 49 mm. were used to hold the 60-ml. milk samples, and were enclosed in an insulated container for the measurements. The milk was protected during the determinations by a cover with apertures for passage of the wire sup-

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porting the ring and an accurately calibrated thermometer. Milk temperatures were held constant at 60° F. by precooling the milk and containers and carrying out the determinations in a constant-temperature room at 68° F. Temperatures of 81 and 102° F. were held constant by the use of a small 10-watt heating coil embedded in the insulated container. The ambient temperature for measurements at 102 and 81° F. was approximately 80° F.

Determinations of surface tension were made on 72 samples of various milks, of which 27 were raw skimmilk, 23 were pasteurized, homogenized milk from five sources (four commercial), and 22 were raw, whole milk. The number of samples of each milk tested at the temperatures of 60, 81, and 102° F. were, respectively: skimmilk, 7, 4, and 16; homogenized milk, 8, 7, and 8, and whole milk, 5, 4, and 13. Either two or three readings were made on each sample and the results were averaged for each determination. The temperatures of main interest were 60 and 102° F. Some values at the midway point of 81° were obtained, in order to plot curves. Half of the skimmilk samples were a few hours old and half were about one day old. The age of the whole milk samples varied from a few hours to about 12 hr. The age of the commercial, homogenized milk was estimated to be about two days.

Fat determinations were made on all samples of milk, with the exception of two of skimmilk. The DPS detergent method *(14)* was used for milk and the American Association[3] modified Babcock method *(7)* for skimmilk. The skimmilk samples ranged in fat content from 0.03 to 0.08%, with one of 0.22%. The commercial, homogenized milks ranged from 3.4 to 3.7% fat, with two laboratory homogenized samples of 2.5 and 6.2% fat. The whole milk samples varied in fat content from 3.1 to 7.7%.

RESULTS

The surface tension, as calculated from least-squares regression equations, and their standard errors of estimate for the different milks over the temperature range of 60–102° F., are shown (Figure 1). The results show that there was a consistent difference in the surface tensions of skimmilk, whole milk, and homogenized milk, with an increasing divergence apparent with a rise in temperature. The surface tension of the homogenized milk fell about midway between that of the other milks. The fact that there was an increase of about 50% in the difference in surface tension between skimmilk and whole milk when the temperature was raised from 60 to 102° is of importance in the calibration of lactometers at the higher temperature. The rate of change in the surface tension with increased temperature for all milks was greatest between 60 and 80° F.

The surface tension of skimmilk and whole milk containing various percentages of fat is shown (Figure 2). The points for skimmilk are average values, whereas those for whole milk are individual values. The data show a definite difference between the surface tension of skimmilk and that of whole milk. It is also evident that surface tension is not greatly affected by a fat content in

[3] American Association of Creamery Butter Manufacturers.

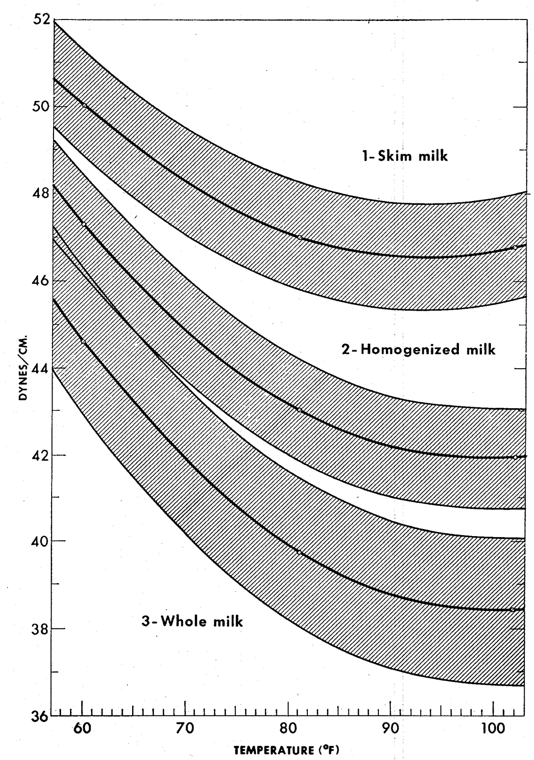

FIG. 1. Variation of the surface tension of milks with temperature. Shaded areas indicate the standard errors of estimate.

Y = Surface tension in dynes/cm. X = Temperature in ° F.

1. $Y = 74.25 - 0.5941X + 0.003185X^2$ Standard error of estimate = $\pm$ 1.22
2. $Y = 76.73 - 0.7054X + 0.003574X^2$ Standard error of estimate = $\pm$ 1.16
3. $Y = 77.92 - 0.7953X + 0.004004X^2$ Standard error of estimate = $\pm$ 1.70

excess of 4%. This is in general agreement with the conclusions of Dunkley *(6)*, who worked with reconstituted milk of varying fat content.

The values for the surface tension of skimmilk and whole milk are in good agreement with the results of Dunkley *(6)*, Hetrick and Tracy *(10)*, and Sharp and Krukovsky *(15)*. However, the values are considerably lower than other static surface tension readings on milk reported in the literature, which include those by Cardoso and Wancolle *(3)*, Kopaczewski *(11)*, Nutti *(12)*, Whitnah *et al.* *(20)*, and Velu and Belle *(17)*.

DISCUSSION

The lack of agreement in the published results is not surprising when the influence of the various circumstances involved is considered. Some of the factors are variations in the composition of milks from widely scattered sources, and the age and prior treatment of the samples before measurement. The different types of apparatus, and the methods employed, also affect the precision of the measure-

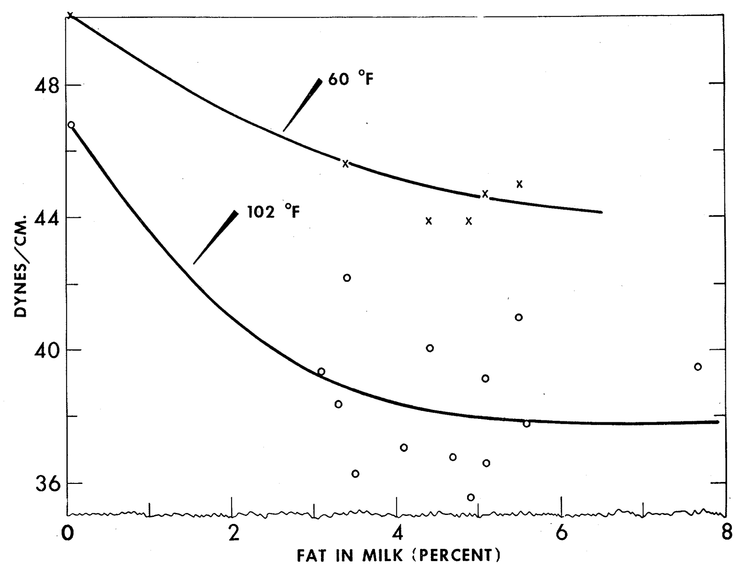

FIG. 2. Effect of fat variations in milk upon the surface tension at 60 and 102° F.

ments. It seems apparent that in some instances a correction factor as suggested by Harkins and Jordan *(8)* and Zuidema and Waters *(21)* was not applied to the results obtained by the ring method, which would result in a positive error of almost 10% in the surface tension when a 6-cm. ring is used. The error would be considerably larger for a 4-cm. ring.

The surface tension of the homogenized milk averaged about three dynes higher than that of the whole milk over the temperature range of 60–102° F. Doan *(5)* and Trout *et al.* *(16)* reported that the surface tension of milk was increased by homogenization if the milk was pasteurized before processing. Doan attributed the increase to the greater protein adsorption by the fat resulting from the increase in the fat surface.

It is well known that the development of rancidity in milk markedly lowers the surface tension. The homogenization of raw milk sometimes results in a lowering of the surface tension and this effect may be due to lipase action. This would not be a significant factor in the surface tension studies of pasteurized, homogenized milk reported here.

Some workers have reported that milk on aging undergoes a small decrease in surface tension which appears to be due to solidification of the fat or to lipase action. However, experiments in this study showed a decrease of only about one dyne for herd milk and no change for commercial homogenized milk in the surface tension at 81° F., when the milks were held at 32° F. for two and three days, respectively.

Burri and Nussbaumer *(2)* and Bauer *(1)* noted a decrease in the surface tension of milk with time, and attributed it to the solidification of the fat, because the surface tension returned to its former value when the milk was heated for 30 min. at 50° C.

Whitnah *et al.* (*20*) also found that the condition of the milk fat affected the surface tension readings. They reported a decrease in the surface tension of commercial homogenized milk held for seven days at about 5° C. over the same milk held for one day and then warmed to 15, 25, and 30°. The decrease was 5.5, 2.9, and 1.3 dynes, respectively. However, when the milk was warmed to 40, 50, and 60° C., the changes in surface tension were negligible. This information indicates that the surface tension of milk tends to be more uniform, regardless of age, when milk is heated to a temperature at which the fat is in a liquid condition, which is a point in favor of using a heating method for lactometer readings.

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